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(71) Applicant
Dr. Eugen Dürrwächter Doduco,
Westliche Karl-Friedrich-Str. 61, D—7530 Pforzheim, West Germany

(72) Inventor
Hans-Jürgen Gevatter

(74) Agent
Cruikshank & Fairweather,
19 Royal Exchange Square, Glasgow, G1 3AE

(54) **Induction-Type Position Encoder**

(57) A magnetic induction-type position encoder and displacement detector contains two electrical windings 2, 3 and a bistable magnetic element 1, such as a Wiegand wire, which couples these two windings magnetically. One of the two windings, 3, serves as an exciter winding and is supplied with a periodic voltage signal which produces a periodically changing magnetic field. This field causes a periodic change in magnetic polarity of the bistable magnetic element 1. The periodic change in polarity induces in the second winding 2 a periodic train of electrical voltage pulses, the phase of which relative to the exciter signal can be influenced in relation to position by moving permanent magnets 6, 7 closer to or further away from the bistable magnetic element 1.

Fig.1

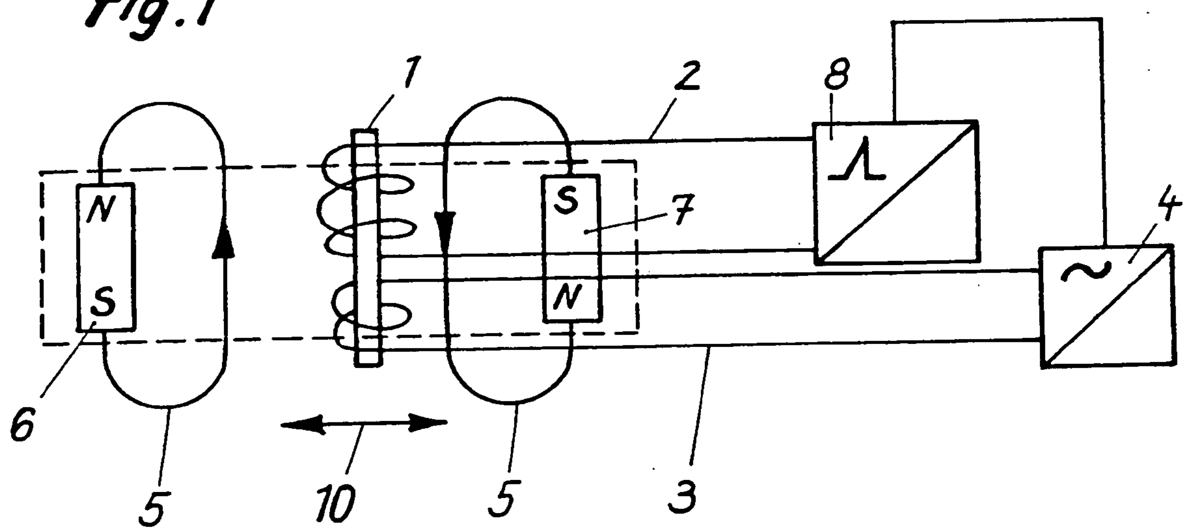

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Fig.1

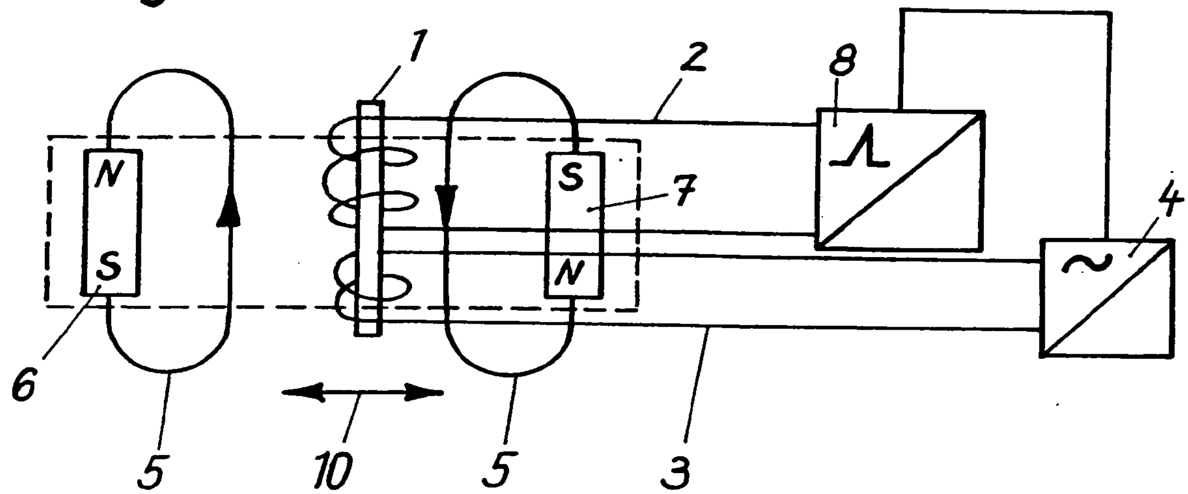


Fig.2

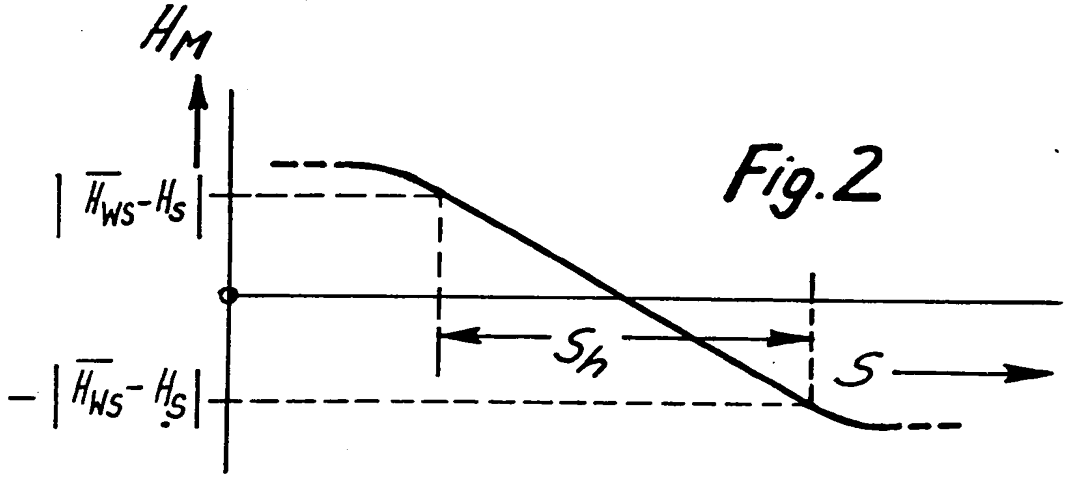
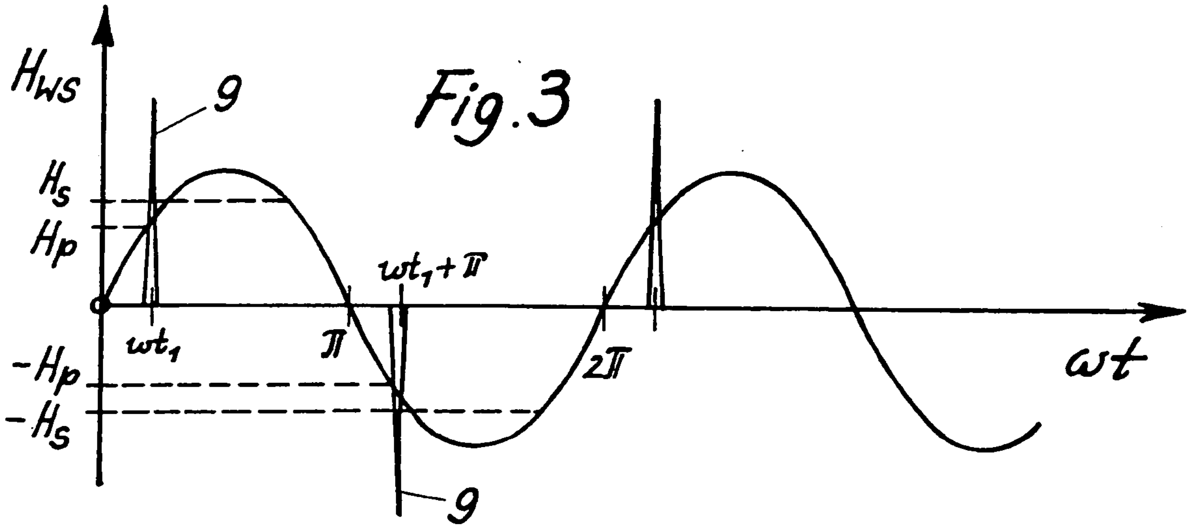


Fig.3



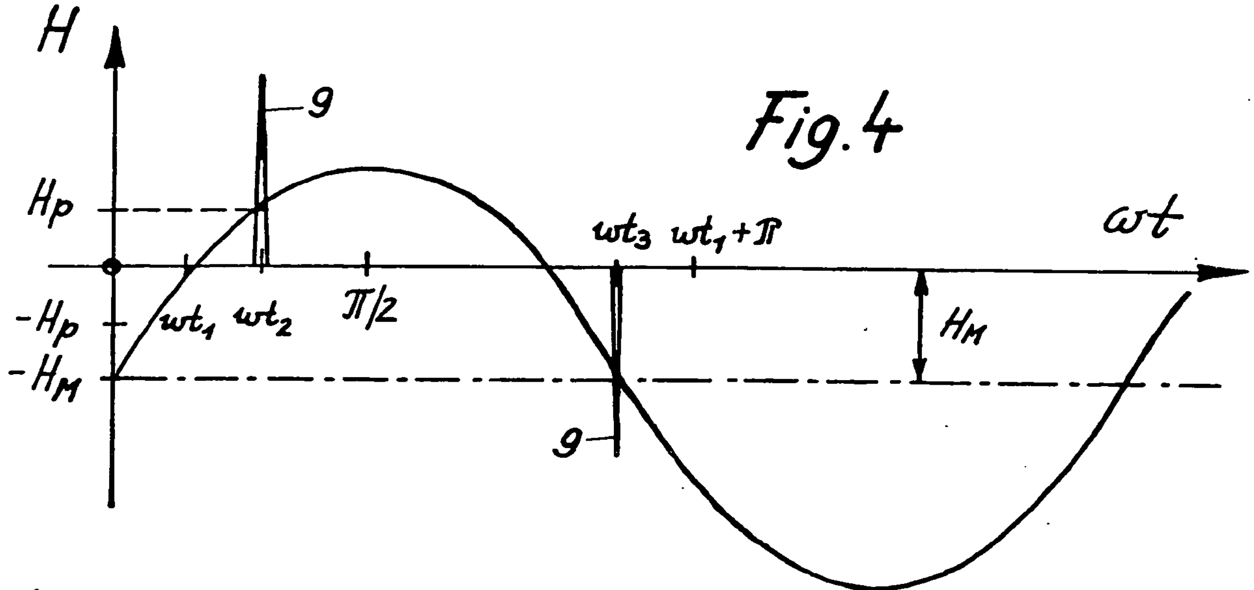


Fig. 4

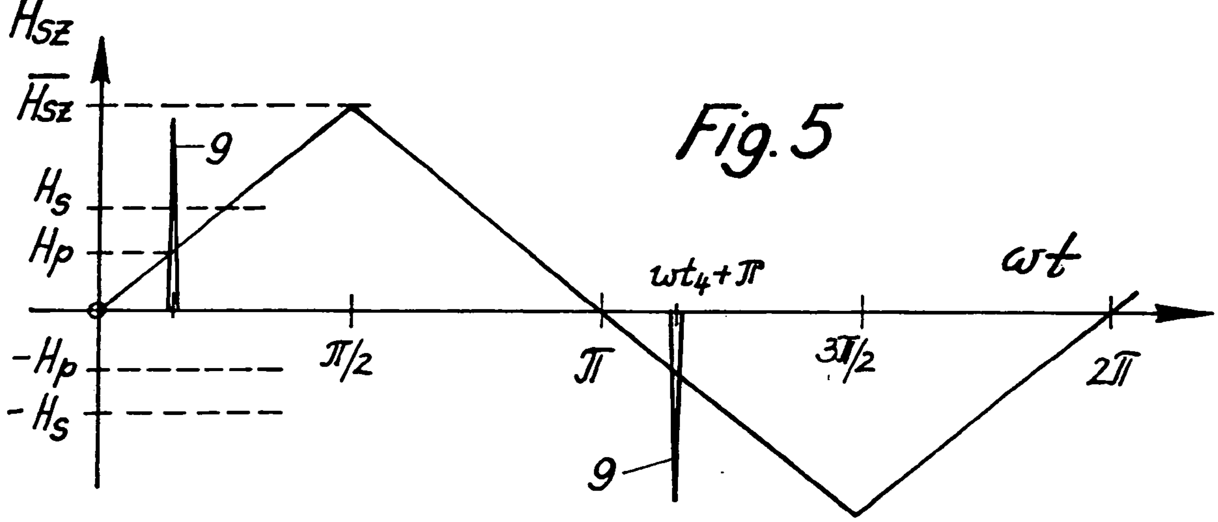


Fig. 5

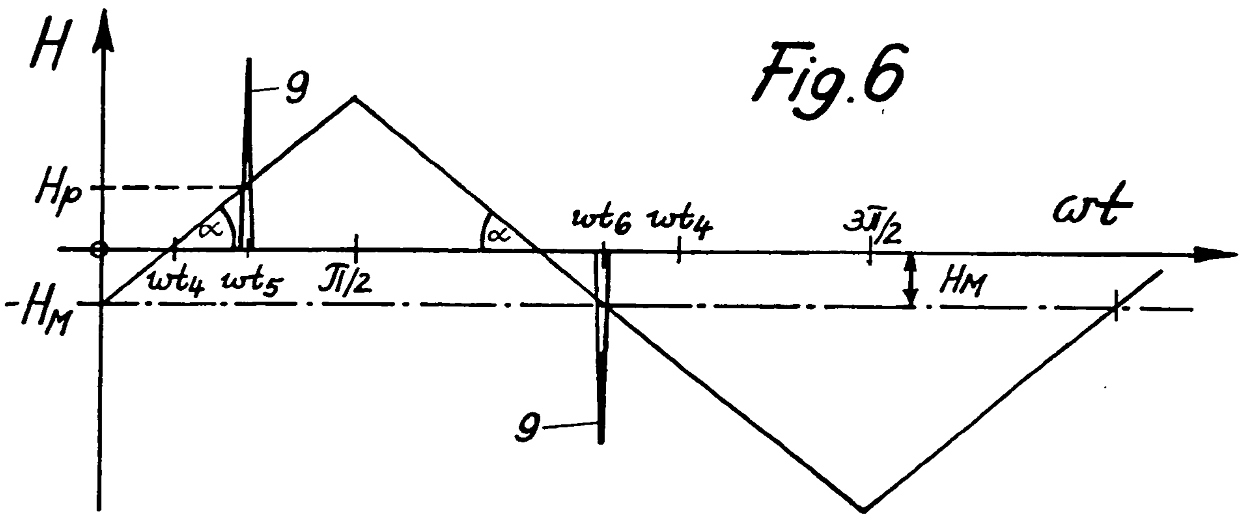


Fig. 6

SPECIFICATION
Induction-type Position Encoder

The invention relates to a position encoder of induction type. An exciter winding is a winding to which a periodic voltage signal of constant amplitude is supplied. This voltage signal is employed to produce in a second winding (sensor winding) an electrical response signal, whereby the coupling between the two windings bears a predetermined relationship to the length of path to be measured, and the kind of response signal produced in the sensor winding is consequently dependent upon the length of path which a body has covered, or as the case may be the position at a given moment of such a body.

It has previously been proposed, in a position encoder of induction type, to provide the coupling between the exciter winding (primary winding of the transformer) and the sensor winding (secondary winding of the transformer) as path-dependent by changing the position of a ferromagnetic core which links the two windings, or by moving ferromagnetic parts towards or removing them from the arrangement, which moreover is fixed, of the windings and of a core linking these, whereby the transformer coupling is strengthened or weakened. The body, whose movement or position is to be monitored, may itself by the ferromagnetic core, or a separate ferromagnetic part acting upon the windings, or may be coupled therewith by way of gear elements, so that in any case the change of position of the body is associated directly with a change in the coupling between the two windings.

In previously proposed induction-type position coders, an alternating current of constant amplitude is fed to the exciter winding and the amplitude of the alternating voltage signal produced as response in the sensor winding is a measure for the position, or change of position, of the monitored body. The response signal is thus an amplitude-modulated alternating voltage. Therefore, the evaluation circuit placed after the sensor coil must be very accurately adapted to ensure that the amplitude of the response signal is relayed very accurately in respect of the measurement value and not falsified.

An object of the present invention on the other hand is to offer a position encoder of induction-type to produce a response signal which can be evaluated by simple means with accuracy.

According to the present invention there is provided induction-type position encoder with an electrical exciter winding, an electrical sensor winding, and a ferromagnetic core which couples the exciter winding and the sensor winding magnetically together, whereby the exciter winding is supplied with a periodic voltage signal and the electrical response signal produced in the sensor winding is a measure for the length of path to be measured, characterised in that said ferromagnetic core is a bistable magnetic element (hereinafter referred to as BME), in that means are provided for the production of a time-invariable magnetic field which superimposes the BME and, at the location of the BME, has a gradient of the magnetic field strength, and in that the BME and the means for producing the magnetic field are displaceable relative to each other, whereby the direction of the relative movement possesses a component which is parallel to the gradient of the magnetic field strength at the location of the BME.

As bistable magnetic elements, also referred to as bistable magnetic switch cores (and hereinafter and in the claims referred to as BMEs), it is recommended in particular that so-called Wiegand wires be employed, whose structure and manufacture are described in DE—OS 21 43 326. Wiegand wires are homogeneous, ferromagnetic wires (e.g. of an alloy or iron and nickel, preferably 48% iron and 52% nickel; or of an alloy of iron and cobalt; or of an alloy of iron with cobalt and nickel; or an alloy of cobalt with iron and vanadium, preferably 52% cobalt, 38% iron and 10% vanadium) which, due to special mechanical and heat treatment, possess a soft magnetic core and a hard magnetic outer surface, i.e. the surface possesses higher coercive force than the core. Typical Wiegand wires have a length of 5 mm to 50 mm, preferably 20 mm to 30 mm. If a Wiegand wire, in which the direction of magnetisation of the soft magnetic core coincides with that of the hard magnetic surface, is introduced into an external magnetic field whose direction coincides with that of the axis of the wire, but is opposed to the direction of magnetisation of the Wiegand wire, on exceeding a field strength of approximately 16 A/cm, the direction of magnetisation of the soft core of the Wiegand wire is reversed. This reversal is also referred to as resetting. On further reversing of the direction of the external magnetic field, and on the external magnetic field exceeding a critical field strength, the direction of magnetisation of the core is again reversed, so that the core and the surface are again of parallel magnetisation. This reversal of the direction of magnetisation occurs very abruptly and is accompanied by a correspondingly notable change in magnetic flux per unit of time (Wiegand effect). In an induction coil, this alteration of magnetic flux may induce a short and very high voltage pulse (according to the number of turns and to the load resistance of the coil, up to approximately 12 v.) known as a Wiegand pulse.

Also on returning of the core, a pulse is produced in an induction coil, which is however of much lower amplitude and of a different sign from the case of the reversal from the anti-parallel to the parallel direction of magnetisation.

If, as external magnetic field, an alternating field is selected, which is capable of reversing magnetisation firstly of the core and then also of the surface layer and of bringing th se to magnetic saturation, Wiegand pulses occur, due

to the reversal of the direction of magnetisation of the soft magnetic core, alternately of positive and negative polarity, which is termed symmetrical excitation of the Wiegand wire. For this purpose field strengths of approximately —(80 to 120 A/cm) to +(80 to 120 A/cm) are required. The change of magnetisation of the surface also occurs abruptly and also produces a pulse in the induction coil, which is however much smaller than the pulse induced in the reversal of the core and is generally not evaluated.

If however an external magnetic field is selected which is capable of reversing only the soft core but not the hard surface layer in direction of magnetisation, the high Wiegand pulses occur only with unchanged polarity which is referred to as asymmetrical excitation of the Wiegand wire. For this purpose, a field strength is required in one direction of at least 16 A/cm (for the resetting of the Wiegand wire) and in the opposite direction a field strength of approximately 80 to 120 A/cm.

It is characteristic of the Wiegand effect that the amplitude and width of the pulses it produces are largely independent of the speed of change of the external magnetic field and that they possess a high signal-to-noise ratio.

Also suitable for the purpose of the invention are differently constructed bistable magnetic elements which possess two zones of differing magnetic hardness (coercive force) magnetically coupled to each other, and may be employed in the same manner as Wiegand wires for producing pulses by an induced, abrupt reversal of the soft magnetic zone. Thus, a bistable magnetic switch core in the form of a wire has previously been proposed in, for example, DE—PS 25 14 131 which comprises a hard magnetic core (e.g. of nickel-cobalt), an electrically conductive intermediate layer (e.g. of copper) deposited thereon, and a soft magnetic layer (e.g. of nickel-iron) deposited thereon. Another variant additionally employs a core of a magnetic, non-conductive metal inner conductor (e.g. of beryllium-copper), on to which the hard magnetic layer is deposited, then on this the intermediate layer, and on this the soft magnetic layer. This bistable magnetic switch core does, however, produce smaller switch pulses than a Wiegand wire.

At the position of the BME, the time-invariable magnetic field and the periodic magnetic field produced by the excited winding are superimposed to form a periodic magnetic alternating field which causes the BME periodically to change its magnetic polarity, i.e. to reverse the direction of magnetisation of its soft magnetic, and possibly of its hard magnetic portions. The p riodic change of magnetic polarity of the BME is effected abruptly and leads to the production of a train of characteristic pulses in the sensor coil. The point of time for the release of these pulses is dependent upon the reciprocal action of the time-invariable with the periodic magnetic field since, for the release of the pulses, the resulting alternating magnetic field at the location of the BME must exceed in both directions the threshold values conditioned by the characteristics of the BME. Consequently, when the strength of the resulting magnetic alternating field changes, the phase position of the pulses produced also changes in relation to the phase of the periodic exciter voltage signal. Thus, the response signal of the position encoder according to the invention is a phase-modulated train of pulses with constant pulse-height which is true to the measurement value and can be further processed in digital and also in analogue manner in a following evaluation circuit.

With predetermined amplitude of the time-periodic magnetic field produced by the exciter winding at the location of the BME, the effective range of the position encoder is spatially restricted to values of the field strength of the time-invariable magnetic field. This field strength is smaller by at least the field strength required for resetting the BME (with asymmetrical excitation), or that required for change of magnetisation of the hard magnetic portion of the BME (with symmetrical excitation), than the amplitude of the magnetic field produced by the exciter winding, because only then is the resulting magnetic field capable of reversing the poles of the BME magnetically after every sign change. The term "resetting" of the BME refers to the reversal of the direction of magnetisation of the soft magnetic portion from parallel (relative to the magnetisation direction of the hard magnetic portion) to anti-parallel orientation.

It is manifest that the evaluation of the response signal is particularly simple when as far as possible a linear relationship exists between the phase position of the response pulses and the change of position of the body. It is therefore advantageous if the gradient of the time-invariable magnetic field is as far as possible constant and if the voltage signal supplied to the exciter winding in each cycle possesses as far as possible a linear voltage course in time. Means for the linearisation of the spatial course of the time-invariable magnetic field belong to the prior state of the art.

The time-invariable magnetic field is preferably produced by permanent magnets, although basically, electromagnets may also be employed for this purpose.

In order to obtain the maximum possible effective range of the position encoder, and to facilitate linearisation of the time-invariable magnetic field, it is preferred that such a field should possess a zero-crossing (sign change) of magnetic strength, and that this zero-crossing of field strength should preferably lie in the centre of the spatial effective range of the encoder. This advantage may, however, be fully utilised only where the periodic magnetic field of the exciter winding is at the same time an alternating field, whereby both the time-invariable magnetic field and the magnetic alternating field are preferably

of symmetrical form in respect of their particular zero-crossing.

Here it is also true that the spatial effective range of the position encoder is restricted to values of the field strength of the time-invariable magnetic field which are so much smaller than the amplitude of the magnetic alternating field that, after each sign change of the resulting magnetic field, reversal of the direction of magnetisation can occur. Thus, since the field strength of the time-invariable magnetic field must in any case maintain a certain distance from the amplitude of the magnetic alternating field, a sinusoidal alternating voltage may be employed with great advantage as exciter voltage signal in order to form the magnetic alternating field, because, within a considerable range on both sides of the zero-crossings, this voltage is already to a large extent linear in time. At the margins of the effective range, i.e. utilising the magnetic field of the exciter winding in the vicinity of the time-peak values of magnetic field strength, a linearity correction can be applied to the response signal by means of circuitry technology. This linearity correction becomes unnecessary if a saw-tooth form of voltage signal in which the two edges of each tooth are of identical steepness is employed initially for supplying the exciter winding.

The position encoder according to the invention may operate with asymmetrical excitation of BME, especially in the case where the time periodic magnetic field produced by the exciter winding is a pulsating direct field which is opposed by the time-invariable magnetic field whereby the resulting magnetic field is an alternating field. With predetermined amplitude of the pulsating direct field, the effective range of the position encoder is a function of the field strength of the time-invariable magnetic magnetic field at the location of the BME. The field strength of the time invariable field must be at least at such a level that the resulting alternating field at the location of the BME is, in one direction (negative), at least of such a strength that it can return the BME, i.e. that it is capable of changing the soft magnetic portion of the BME from the parallel direction of magnetisation to a direction which is anti-parallel to the magnetisation direction of the hard magnetic portion. Furthermore, the field strength of the time-invariable field may be only of such a level at the location of the BME that the resulting field strength is just sufficiently strong to change the magnetisation of the BME from anti-parallel again to parallel magnetisation of its portion, whereby a high, characteristic pulse is produced in the sensor winding.

Employing a Wiegand wire as BME, normally a resulting field strength of appx. −16A/cm is required for resetting, whilst, for changing magnetisation to parallel orientation as far as the saturation area, a resulting field strength of appx. 80 to 120 A/cm is normally required. If the given minimum field strength of the time-invariable magnetic field is not attained, the BME can no longer be magnetically returned. If the field strength of the time-invariable magnetic field exceeds the given maximum, in spite of resetting, the poles of the BME can no longer be changed magnetically to parallel orientation; in both cases, the characteristic pulses no longer occur. If, however, the field strength of the time-invariable magnet field increases beyond the given maximum, it may happen that the resulting magnetic field is so strong in the opposite direction that the magnetisation of the magnetically hard portion of the BME is reversed, so that asymmetrical excitation of the BME again occurs, which produces however pulses of reversed polarity in the sensor winding.

Preferably, however, the position encoder should be operated with symmetrical excitation of the BME, in which case the encoders of the foregoing type are particularly suitable. With symmetrical excitation and a predetermined positive and negative amplitude of the magnetic alternating field, the effective range of the position encoder is then limited by the fact that, at the location of the BME, the field strength amplitudes of the resulting magnetic alternating field in both directions are sufficiently great to change the magnetisation not only of the soft magnetic portion but also of the hard magnetic portion. If this condition is maintained, a train of pulses with alternating sign is obtained in the sensor winding, whereby the position of the pulses in relation to the phase of the exciter voltage signal is a measure for the position, or change of position, of the monitored body.

If the condition described is not maintained but the BME is moved into an area of higher field strength of the time-invariable magnetic field, the symmetrical excitation of the BME is converted firstly into an asymmetrical excitation of the BME, with the result that, in the sensor winding, the pulses of one polarity are missing; the polarity of the pulses which do occur is dependent upon the direction in which the effective range of the symmetrical excitation is exceeded.

The effective range of the symmetrical excitation of the BME is preferably linearised. When the threshold between symmetrical and asymmetrical excitation is exceeded, the evaluation circuit connected to the sensor winding may, with advantage, be so constructed that it delivers a warning signal which indicates that the linear effective range of the encoder has been exceeded and in which direction.

Whether the BME is at rest and the time-invariable magnetic field is displaced or vice versa, has no significance for the principle of operation of the position encoder; both are possible. Movement of the time-invariable magnetic field may be effected by movement of the magnets producing it, but, in the case of stationary magnets, it may also be effected by the movement of ferromagnetic conductive elements.

The exciter winding and the sensor winding may be arranged basically in the proximity of the

BME, provided that thereby a magnetic coupling with the BME can be achieved in sufficient degree. Preferably however, both exciter winding and sensor winding are placed actually around the BME. Moreover, to obtain a high signal yield, a Wiegand wire should preferably be employed as BME.

It is also preferable that the two magnetic fields which are superimposed upon each other possess at the location of the BME a parallel field-lin characteristic, preferably parallel to the longitudinal axis of the BME.

Normally, position encoders convert linear movements, or changes of position of linear type, into an output signal. In the present case, it is also possible to employ the position encoder as a rotary angle indicator. This is possible provided that, over a suitable azimuth angle range, the time-invariable magnetic field possesses a gradient of field strength in azimuth direction, which (corresponding to the case of a linear position encoder) should be constant over the c rresponding azimuth angle range (effective range), and should be connected to a zero-crossing of the field strength.

Embodiments of the present invention will now be described by way of example, with reference to the accompanying diagrammatic drawings, in which:

Fig. 1 shows the schematic structure of a position encoder according to the invention;

Fig. 2 shows the course of a time-invariable magnetic field which is suitable for the position enc der;

Fig. 3 is a diagram to explain the phase position of the response pulses occurring where excitation of the exciter winding is effected with a sinusoidal alternating voltage, and the Wiegand wire is arranged in the zero-crossing of the time-invariable magnetic field;

Fig. 4 is a diagram corresponding to Fig. 3, wilh displacement of the Wiegand wire out of the zero-crossing of the time-invariable magnetic field, and

Figs. 5 and 6 are diagrams corresponding to Figs. 3 and 4, but with employment of a saw-tooth form alternating voltage for excitation of the exciter winding.

Referring to Fig. 1 of the drawings, a position encoder comprises a Wiegand wire 1 as bistable magnetic element, an exciter winding 3 connected to a source of alternating voltage 4 which, together with sensor winding 2, directly encloses the Wiegand wire, and an evaluation circuit 8 which is placed after the sensor winding 2 and determines the kind and phase position of the voltage pulses occurring in the sensor winding 2. Two bar magnets 6 and 7 are also provided which are disposed on both sides parallel to the Wiegand wire 1 and having magnetisation directions which are anti-parallel to each other, so that the magnetic field 5, which is produced between these two magnets 6 and 7, has a zero-crossing, i.e. there is reversal of direction of the magnetic flux. Assuming that the two magnets 6 and 7 are equally strong and that the magn tic field 5 is not distorted by external influences, this zero-crossing of the magnetic field strength is located centrally between the two magnets 6 and 7. The course of field strength $H_M(s)$ of such a magnetic field is shown in Fig. 2, in which *s* indicates the path between the two magnets 6 and 7 following a straight line.

If the exciter winding 3 is fed with a sinusoidal alternating voltage, the exciter winding 3 produces a magnetic field which is approximately sinusoidal in time and which fluctuates at the position of the BME according to the formula:

$$\text{(I)} \qquad H_{WS}=\overline{H}_{WS}\cdot \sin \omega t$$

Here, H_{WS} is the magnetic field strength of the alternating field at the position of the Wiegand wire 1, $\overline{H}_{WS}$ is its amplitude, *t* is time, and ω the angular frequency of the exciter alternating voltage. If only the magnetic alternating field H_{WS} is effective at the position of the Wiegand wire 1, and if its amplitude is greater than the field strength H_S required for the symmetrical change of magnetisation of the Wiegand wire 1, (Fig. 3):

$$\text{(II)} \qquad \overline{H}_{WS}>H_S$$

(where H_S with Wiegand wires lies in the region of $\pm$(80 to 120) A/cm, then, at a certain field strength H_p, which is smaller than the field strength H_S, the great characteristic Wiegand pulses 9, shown in Fig. 3, are produced. At the field strength H_p the magnetisation of the soft magnetic core of the Wiegand wire 1 is reorientated from the anti-parallel to the parallel direction. At the field strength H_S the magnetisation direction of the hard magnetic outer surface of the Wiegand wire is then reversed. At the same time, a pulse is also produced in the sensor winding 2, which is however much smaller than the pulse 9 occurring at H_p and is hereinafter ignored. This can be suppressed by a simple discriminator circuit.

In the absence of the field 5 (H_M=O), the Wiegand pulses occur in the phase positions ωt_1 and $\omega t_1+\pi$. This corresponds to the case where the Wiegand wire 1 lies exactly in the zero-crossing of the magnetic field 5 (H_M=O).

Now, if the Wiegand wire 1 is moved in the magnetic field 5 in the direction of the arrow 10 towards one of the magnets 6 or 7, there is superimposed upon the alternating field

$$H_{WS}=\overline{H}_{WS}\cdot \sin \omega t$$

a direct field $H_m(s)$, whereby (according as to which of the magnets 6 or 7 the Wiegand wire is moved towards) the magnetic alternating field H_{WS} is "raised" or "lowered". The changed conditions resulting from this can be read from Fig. 4 which shows the time-course of the resulting magnetic field

$$\text{(III)} \qquad H=H_{WS}-H_M$$

The Wiegand pulses 9 now occur in the phase positions ωt_2 and ωt_3 which are displaced relative to the initial positions ωt_1 and $\omega t_1+\pi$, towards the peak value, lying therebetween, of the field strength in the phase position $\pi/2$. Provided that

$$H_M \ll \overline{H}_{WS}$$

the change in phase position of the Wiegand pulses 9 occurs in the area of linear dependence of the field strength H_{WS}, or $H_{WS}-H_M$ upon the phase ωt.

If it is desired to obtain a linear relationship over the entire phase range between the phase position of the Wiegand pulses 9 and the time-invariable magnetic field H_M, this can be achieved by employing an alternating voltage of saw-tooth waveform to supply the exciter winding 3. The magnetic field H_{SZ} of the exciter winding 3 has then also an approximately saw-tooth waveform course (Fig. 5). When the Wiegand wire 1 is in the zero-crossing of the time-invariable field 5 ($H_M=0$), the Wiegand pulses 9 have the phase positions ωt_4 and $\omega t_4+\pi$ (Fig. 5). If the Wiegand wire 1 is moved in the direction of the arrow 10, thus causing a direct field H_M to be superimposed upon the alternating field H_{SZ}, the phase positions of the Wiegand pulses 9 are displaced to the values ωt_5 and ωt_6, which are displaced from the original phase positions ωt_4 and $\omega t_4+\pi$ in the direction of the field strength in the phase position $\pi/2$, whereby the displacement of the phase positions is proportional to the field strength H_M:

(IV) $$\omega(t_5-t_4)=K_1 \cdot H_M$$

(V) $$\omega(t_4+\pi-t_6)=K_2 \cdot H_M$$

The constants K_1 and K_2 are dependent upon the steepness of the two edges of each saw-tooth of the magnetic alternating field. If, as in the example illustrated, both edges are selected with identical steepness, then:

$$K_1=K_2$$

and the Wiegand pulses 9 of both polarities undergo this same phase displacement, which is dependent in linear fashion upon the field strength H_M.

If, in addition, the local course of the magnetic field H_M is linearised, so that

(VI) $$H_M=K_3 \cdot s$$

in which K_3 is a constant, then the phase displacement of the Wiegand pulses 9 is also dependent in linear fashion upon the displacement Δs in the magnetic field 5.

Symmetrical excitation of the Wiegand wire 1 occurs, provided:

(VII) $H_M<\overline{H}_{WS}-H_S$ (Fig. 3)

or

(VIII) $H_M<\overline{H}_{SZ}-H_S$ (Fig. 5).

If these values are exceeded, the excitation is changed to asymmetrical excitation, in which every second Wiegand pulse is missing, so that the remaining pulses are left with only one polarity.

Asymmetrical excitation ends when

(VIIa) $H_M>\overline{H}_{WS}-H_R$

or as the case may be,

(VIIIa) $H_M>\overline{H}_{WS}-H_R$

in which H_R is the field strength required for magnetic resetting of the Wiegand wire (appx. 16A/cm).

The limit value from the expression (VII) is shown in Fig. 2.

The effective range S_h of the position encoder is determined from this.

Claims

1. An induction-type position encoder with an electrical exciter winding, an electrical sensor winding, and a ferromagnetic core which couples the exciter winding and the sensor winding magnetically together, whereby the exciter winding is supplied with a periodic voltage signal and the electrical response signal produced in the sensor winding is a measure for the length of path to be measured, characterised in that said ferromagnetic core is a bistable magnetic element (hereinafter referred to as BME), in that means are provided for the production of a time-invariable magnetic field which superimposes the BME and, at the location of the BME, has a gradient of the magnetic field strength, and in that the BME and the means for producing the magnetic field are displaceable relative to each other, whereby the direction of the relative movement possesses a component which is parallel to the gradient of the magnetic field strength at the location of the BME.

2. A position encoder according to claim 1, in which said means for the production of the time-invariable magnetic field are so constructed and arranged that the gradient of this magnetic field is constant over a certain area of the length of path *s* to be monitored.

3. A position encoder according to claim 1 or 2, in which the periodic, electrical voltage signal supplied to the exciter winding possesses in every cycle a voltage course which is linear in time.

4. A position encoder according to claim 3, in which the voltage signal is of saw-tooth waveform, whilst the two edges of each tooth are of identical steepness.

5. A position encoder according to any preceding claim, in which the means for producing the time-invariable magnetic field comprise a permanent magnet or arrangement of permanent magnets.

6. A position encoder according to any preceding claim, in which the time-invariable magnetic field is so constructed that, in a spatial

effective range S_h of the position encoder, it possesses a zero-crossing (sign change) of its magnetic field strength, and in that the magn tic field produced by the exciter winding, which is periodic in time, is an alternating field.

7. A position encoder according to claim 6, in which the zero-crossing of the time-invariable magnetic field lies approximately in the centre of a field strength zone with constant spatial gradient of the field strength, and in that the magnetic alternating field produced by the exciter winding at the location of the BME is symmetrical in respect to its periodic zero-crossings (sign changes) of its field strength.

8. A position encoder according to claim 6 or 7, in which the exciter winding is supplied with an alternating voltage of sinusoidal waveform.

9. A position encoder according to claim 6 or 7, in which the exciter winding is supplied with an alternating voltage of sinusoidal waveform, in which the two edges of each tooth are of identical steepness.

10. A position encoder according to any of claims 6 to 9, in which, after the sensor winding is placed an elevation circuit, which, in the absence of pulses of one of two polarities, delivers a predetermined signal.

11. A position encoder according to any preceding claim, in which the exciter winding is placed directly around the BME.

12. A position encoder according to any preceding claim, in which the sensor winding is placed directly around the BME.

13. A position encoder according to any preceding claims in which the BME is a Wiegand wire.

14. A position encoder according to any preceding claim, in which the periodically time-variable magnetic field and the time-invariable magnetic field possess at the location of the BME a field-line course which is substantially parallel.

15. A position encoder substantially as hereinbefore described with reference to the accompanying drawings.

16. A method of using a position encoder according to one of the foregoing claims, in which the time-invariable magnetic field possesses a gradient of field strength in azimuth direction, as rotary angle indicator.

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